Research Proposal Form of the Thesis Entitled

Effect of various torque and speed control settings on endodontic rotary file

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Introduction -

NiTi Rotary files have become an essential part of root canal biomechanical preparation. Unlike the stainless steel file system used earlier, NiTi files have properties such as super elasticity and shape memory. These properties help them to navigate the canal better without causing ledge formations in the canal [1]. Despite these improvements the issue of file separation is still a challenge with these files also [2].

The two main reasons for file separation in either stainless steel file or rotary file is cyclic fatigue and torsional failure [3]. The reason for cyclic fatigue is that when a file is continuously rotated in a canal or is used over a period of time in such a way, stresses develop in the file leading to microcrack formations, which ultimately lead to fracture of the file. While on the other hand torsional failure occurs when some portion of file gets stuck or engaged in a narrow part of the canal and the file keeps rotating, in such case the elastic limit of alloy gets surpassed and file gets separated [4]. In both kinds of failure, settings of Torque control and speed play a crucial role [5].

Nowadays all rotary files are to be used along with a speed reduction endodontic motor, which plays a major role in regulating kinematics of the file. All files come with recommended torque and speed settings for optimal performance [6]. However, to achieve better cutting efficiency or to push rotary file in narrow sclerotic canals, clinicians sometimes alter with the settings, this practice is useful many a times but can also hasten file separation if used without understanding [7],[8].

While the majority of studies rely on manufacturer's recommended settings only for testing the physical property of files there is no clarity of how altering the speed and torque setting in severely curved canals could improve or degrade the outcome [9]. A few studies also study performance of files in different kinematics [10], but there is still a knowledge gap as to what is safe range of file to be used in various speed and torque control settings to achieve better efficiency.

Hence the purpose of this study is to use various combinations of speed and torque control settings in severely curved canals to test failures due to cyclic fatigue and torsional stress.

Statement of Problem

Nickel-Titanium (NiTi) rotary instruments are prone to fracture due to cyclic fatigue and torsional stress, which can cause failure of root canal treatment
Although manufacturers recommend fixed speed and torque settings, there is lack of evidence on how the files perform with altered speed and torque control settings
A systematic study is needed to identify the safest and most effective range of speed and torque settings for NiTi files.

Clinical Implication of the Study

This study will generate data to guide clinicians in choosing safe and effective speed and torque settings ranges for NiTi rotary files. By understanding how different combinations affect cyclic fatigue and torsional resistance, practitioners will be able to adjust motor settings based on canal anatomy, reducing file separation and improving treatment safety and outcomes.

Aims, Objectives, and Hypotheses

Primary Aim

To evaluate how changes in rotational speed (RPM) and torque settings affect the cyclic fatigue resistance (cycles to fracture) and torsional strength (maximum torque at fracture) of a modern NiTi rotary file system.

Objectives

1. To measure and compare the cyclic fatigue resistance and torsional strength of the selected NiTi file at manufacturer-recommended settings and thereafter at higher and lower speed settings while keeping torque constant.
2. To measure and compare the cyclic fatigue resistance and torsional strength of the file at manufacturer-recommended settings and at higher and lower torque settings while keeping speed constant.
3. SEM analysis of damaged file surfaces to verify comprehension of the fracture mechanism

4. To ascertain the ideal torque and speed ratio that offers the best trade-off between torsional strength and fatigue resistance for secure and effective file use.

Proposed Hypothesis

Changes or altering in the endodontic motor settings will significantly affect the mechanical performance of the NiTi rotary file system.

Null Hypothesis

There will be no statistically significant difference in the mean Cycles to Fracture (CTF) and the mean maximum torque at fracture for the manufacturer recommended setting or altered settings.

Review of Literature

In one of the initial studies done by Pruett et al.[11] noted that cyclic fatigue is one of the main factors responsible for fracture of NiTi instruments, especially in curved canals. They observed severe and abrupt canal curvatures are mostly the cause of file separation due to increased flexural stress on the alloy of the files. They reported a very important observation that canal anatomy has a greater influence on durability of instruments rather than the rotational speed.

Later on, Sattapan et al.[12] reported after analysing used files that most rotary files show defects or cracks on their surface after continuous and regular use. They found torsional failure responsible slightly more than cyclic fatigue for instrument breakage. This study added one more factor responsible for the fracture of files apart from gradual fatigue.

A few years later Testarelli et al.[13] came with a new viewpoint that cyclic fatigue and tolerance to fracture of a rotary instrument depend on the twisting production technique. According to them, improvement in metal processing and file design can improve the performance of the file and safety of the rotary instrument.

In the same year Lopes et al.[14] noted the inverse relationship between increased rotational speed and fatigue resistance of rotary files. They observed that increasing RPM caused faster fatigue accumulation. They suggested that using lower speeds can improve the safety of files by minimizing cyclical stress on the alloy.

In the coming years kinematics also evolved. Kim et al.[15] compared reciprocating systems with traditional rotary motion and found that reciprocating movement significantly improved resistance to both cyclic fatigue and torsional stress. This paved the path for use of alternating movement patterns to reduce the strain of the rotating file through engagement and disengagement while cutting through dentine.

In recent years Ribeiro et al.[16] compared conventional and heat-treated NiTi files. They showed that improvement in metallurgy of rotary files improved flexibility and ability to resist cyclic fatigue and torsional stress. The study reinforced that metallurgical advancements continue to improve instrument durability, reducing fracture risk during clinical use.

Further research by Thu et al.[17] brought attention to the use of pecking motion while advancing the rotary file in the root canal. They demonstrated that insertion to an extent with quick withdrawal movement helps in distribution of stress more effectively. The newer heat-treated rotary files performed better than the previous generation ones. They concluded that improvement in technique in combination with improved metallurgy can improve endurance of the rotary file system.

In the most recent study by Caviedes et al.[18] they evaluated newer reciprocating systems using advanced digital analysis. They found that increasing torque settings slightly from the recommended ones could be detrimental to rotating files as it could induce microscopic structural damage. However, they stressed that modern heat-treated reciprocating files show improved cyclic fatigue resistance and have superior torsional strength.

Study Design and Sample Selection

This will be an in-vitro study testing the cyclic fatigue and torsional stress resistance of an endodontic file system under different speed and torque control settings. A total of 30 new heat-treated NiTi rotary files of the same size and taper from the same manufacturing batch will be selected. All the files will be examined under a stereomicroscope to ensure there is no manufacturing defect or any kind of deformation before testing. Each file will then be randomly assigned into any of the five groups. Each group will have a preset combination of rotational speed and torque in the endodontic motor.

Grouping and Operational Parameters

The two variables used in the study will be maximum applied torque (Ncm) and rotational speed (RPM) of a well calibrated endodontic motor system. The manufacturer recommended setting (MRS) will be the control group (G1). The groups will be divided in the following manner

G1 – Manufacturer Control (MRS): 350 RPM, 2.0 Ncm

G2 – High Speed: 450 RPM (+100), 2.0 Ncm

G3 – Low Speed: 250 RPM (−100), 2.0 Ncm

G4 – High Torque: 350 RPM, 3.0 Ncm (+1.0)

G5 – Low Torque: 350 RPM, 1.0 Ncm (−1.0)

Cyclic Fatigue (CF) Testing Protocol

1. **Artificial Canal Simulation:** an artificial canal with curvature in the apical third in a custom-fabricated stainless steel jig will be used as test bed
2. **Method:** each file will be made to rotate in the artificial canal until it fractures.
3. **Outcome evaluation:** time till fracture (TTF) will be recorded after evaluating the video capture of the rotating file till the point of time it fractures

Torsional Resistance (TR) Testing Protocol

1. **Fixture:** The tip of the rotary file will be fixed with a holding device. The apical 3 mm of each instrument will be securely immobilized to simulate binding.
2. **Method:** The file will be rotated at constant rotational speed and fixed torque setting until the file fractures
3. **Outcome evaluation** The file will be rotated at constant rotational speed and fixed torque setting until the file fractures. The torque at fracture will be taken as the applied torque delivered during rotation. Torsional stress will then be calculated using the formula , where d will be the nominal diameter at the fracture level.. The formula used was stress = $16*\text{torque}/\pi d^3$

Fracture Analysis and Microscopic Examination

1. **Macroscopic Examination:** All the separated fragments will be photographed to evaluate external features of fracture.
2. **Steriomicroscope:** Three fractured samples from each group and test type will be chosen for steriomicroscope analysis to closely examine their surface features and notice any the type and extent of microcracks.

Statistical Analysis

All the data will be analysed using the Shapiro–Wilk test. Differences in values among the five groups will be analyzed with one-way ANOVA. When significant differences are found, pairwise comparisons will be performed using Tukey's HSD test, with statistical significance set at $p < 0.05$.

References -

1. Zanza A, D'Angelo M, Reda R, Gambarini G, Testarelli L, Di Nardo D. An Update on Nickel-Titanium Rotary Instruments in Endodontics: Mechanical Characteristics, Testing and Future Perspective-An Overview. Bioengineering (Basel). 2021 Dec 16;8(12):218. doi: 10.3390/bioengineering8120218. PMID: 34940371; PMCID: PMC8698980.

2. Khasnis SA, Kar PP, Kamal A, Patil JD. Rotary science and its impact on instrument separation: a focused review. J Conserv Dent. 2018;21(2):116-124. doi:10.4103/JCD.JCD_240_17

3. Abdellatif D, Iandolo A, Scorziello M, Sangiovanni G, Pisano M. Cyclic fatigue of different Ni-Ti endodontic rotary file alloys: a comprehensive review. Bioengineering. 2024;11(5):499. doi:10.3390/bioengineering11050499

4. Pedullà E, Carlesi T, Pappalardo A, et al. Impact of pecking amplitude on cyclic fatigue of new nickel-titanium files. Clin Exp Dent Res. 2024;10(1):e811. doi:10.1002/cre2.811

5. Fule KJ, Warhadpande MM, Dakshindas D, Muthiah M, Mule A, Wankhade J. Evaluation of cyclic fatigue resistance of nickel titanium rotary instruments: a systematic review and meta-analysis. IP Indian J Conserv Endod. 2023;8(1):13-27. doi:10.18231/j.ijce.2023.004

6. Mangat P, Raina AA, Vaidya S, Bhatacharya A, Dhingra A, Sharma V. Torque and speed in endodontics: a review. Int J Oral Care Res. 2018;6(2):97-100

7. Ha JH, Park SS. Influence of glide path on the screw-in effect and torque of nickel-titanium rotary files in simulated resin root canals. Restor Dent Endod. 2012;37(4):215-219. doi:10.5395/rde.2012.37.4.215

8. Kwak SW, Shen Y, Liu H, Wang Z, Kim HC, Haapasalo M. Heat treatment and surface treatment of nickel–titanium endodontic instruments. Front Dent Med. 2021;2:769977. doi:10.3389/fdmed.2021.769977

9. Rubio J, Zarzosa JI, Pallarés A. A comparative study of cyclic fatigue of 10 different types of endodontic instruments: an in vitro study. Acta Stomatol Croat. 2019;53(1):28-36. doi:10.15644/asc53/1/3

10. Zanza A, D'Angelo M, Reda R, Gambarini G, Testarelli L, Di Nardo D. An update on nickel-titanium rotary instruments in endodontics: mechanical characteristics, testing and future perspective—an overview. Bioengineering (Basel). 2021;8(12):218. doi:10.3390/bioengineering8120218

11. Pruett JP, Clement DJ, Carnes DL Jr. Cyclic fatigue testing of nickel-titanium endodontic instruments. J Endod. 1997;23(2):77-85. doi:10.1016/S0099-2399(97)80250-6

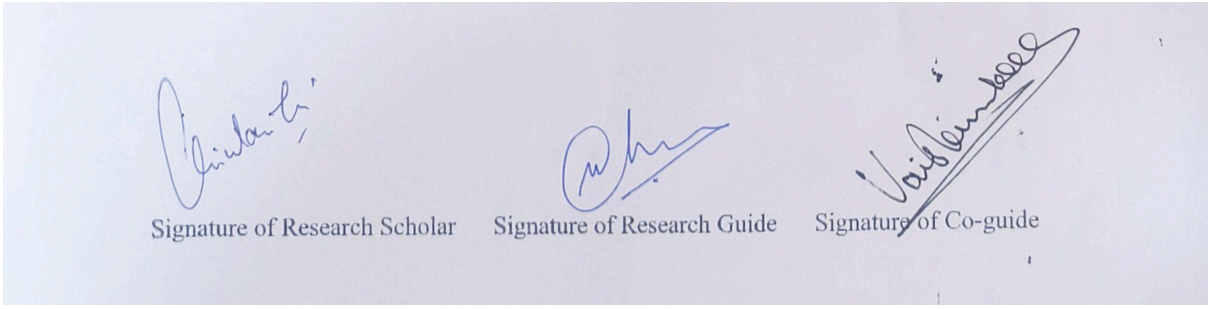
12. Sattapan B, Nervo GJ, Palamara JE, Messer HH. Defects in rotary nickel-titanium files after clinical use. J Endod. 2000;26(3):161-165. doi:10.1097/00004770-200003000-00008

13. Testarelli L, Grande NM, Plotino G, et al. Cyclic fatigue of different nickel-titanium rotary instruments: a comparative study. Open Dent J. 2009;3:55-58. doi:10.2174/1874210600903010055

14. Lopes HP, Ferreira AA, Elias CN, Moreira EJ, de Oliveira JC, Siqueira JF Jr. Influence of rotational speed on the cyclic fatigue of rotary nickel-titanium endodontic instruments. J Endod. 2009;35(7):1013-1016. doi:10.1016/j.joen.2009.04.003

15. Kim HC, Kwak SW, Cheung GS, Ko DH, Chung SM, Lee W. Cyclic fatigue and torsional resistance of two new nickel-titanium instruments used in reciprocation motion: Reciproc versus WaveOne. J Endod. 2012;38(4):541-544. doi:10.1016/j.joen.2011.11.014

16. Ribeiro Camargo CH, Bittencourt TS, Hasna AA, Palo RM, Talge Carvalho CA, Valera MC. Cyclic fatigue, torsional failure, and flexural resistance of rotary and reciprocating instruments. J Conserv Dent. 2020;23(4):364-369. doi:10.4103/JCD.JCD_409_20

17. Thu M, Ebihara A, Maki K, et al. Effect of different axial speed patterns on cyclic fatigue resistance of rotary nickel-titanium instruments. BMC Oral Health. 2022;22(1):617. doi:10.1186/s12903-022-02639-8

18. Caviedes Bucheli J, Teves Cordova A, Alcalde MP, et al. Cyclic fatigue, torsional strength and angular deflection of different reciprocating instruments: a critical analysis of its clinical relevance. Eur Endod J. 2025;10(2):159-172. doi:10.14744/eej.2024.08860